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ABSTRACT

This paper outlines two alternate ways in which concepts are acquired, known as "top down" and "bottom up". "Bottom up" refers to learning the members of a category and then extracting their similarities or differences, the rule or criterial attributes used to make the categorization. In the "top down" approach the essence, or criterial attributes, are pointed out and thus the category elements can be recognized or generated. The paper also discusses the importance of concept learning in schools and the nature of concepts. This investigation was carried out within the framework of the Audio-Tutorial Elementary Science Project at Cornell University. Children were provided with 24 audio-tutorial lessons which dealt with the concepts of energy, life, and molecules. Prior to and subsequent to each block of eight lessons, the children were interviewed to ascertain existing relevant cognitive structure. Two instruments were used: (1) the Modified Piagetian Clinical Interview; and (2) the Conceptual Propositional Analysis. (BB)

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# Alternate Perspectives on Concept Internalization: Learning Top Down Vs. Learning Bottom Up

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## Introduction

The major purpose of this paper is to outline two alternate ways in which concepts are acquired. These two modes of learning, known commonly as "top down" and "bottom up", have been discerned subsequent to an empirical investigation concerning children's acquisition of scientific concepts in an Audio-Tutorial Elementary Science Project (Pines 1977, 1978). The paper is relevant to all those educationists engaged in attempts to meaningfully convey large bodies of conceptual content to students.

Typically in the past, schools have served to transmit cultural content from one generation to the next and to socialize children and adolescents in the mores of our society. However, with the disintegration of extended and nuclear families and the progressive secularization of society, what were once the responsibilities of the home and the church have recently been put upon the schools. It is quite clear that schools cannot bear the entire burden of society (See Ebel 1972); rather, they, in our culture, act to mirror the society. Thus our schools today are unstable and swaying under the aggrevated burden.

Nevertheless, if schools are to fulfill their function of promoting positive change in our ill-ridden culture, children must complete their formal schooling with at least the rudimentary tools of an educated citizen. Such education entails the ability to continue learning in independent situations (viz. learning to learn or life-long learning) and the ability to make rational and moral decisions individually and in groups. Thus, the school cannot act as a surrogate parent, involving itself in child-rearing, home life, and disciplinary action, and still manage to accomplish the difficult tasks of formal, skillful, critical education. I will, therefore, assume that our schools' primary function is to transmit a broad cultural heritage; thus, the purpose

of this paper is to provide the educator with some understanding of how this can best be achieved.

In the first portion of the paper, I will briefly emphasize the importance of concepts and concept learning in the schools. This will provide a rationale and justification for the empirical investigation of concept learning later reported. For, if concept learning were a phenomena of pure academic interest with no relevance to schooling, I would be reluctant to stress the ramifications of such research; even to continue my own efforts in this direction.

In the second portion of the paper, I will focus on the nature of concepts. A formal account of the nature of concepts will be provided so as to enable the interpretation and explanation of the data which follows. This account should be intuitively acceptable to the experienced classroom teacher and thus viewed as pragmatic. Nevertheless, the problems associated with such a clear-cut analysis of "concept" will be stated so as not to leave an oversimplified and incorrect impression.

Finally, the last portion of the paper will detail the author's actual study. The methodology used was a case study approach. The methods for collecting and analyzing the data are novel and will thus need to be briefly explained. Only a small portion of actual data from two case studies will be presented. Nevertheless, these data are sufficient to provide a comparison between the two alternate pathways to concept acquisition which this paper attempts to explain.

## The Importance of Concept Learning

Concepts are the tools of human thought (Toulmin 1972, Elkana 1970, Novak 1977, Pines 1977). As Ausubel (1968, 1978) stresses:

> Anyone who pauses long enough to give the problem some serious thought cannot escape the conclusion that we live in a world of concepts rather than in a world of objects, events, and situations ... Reality, figuratively speaking, is experienced through a conceptual or categorical filter.
>
> (1968, p. 505
> 1978, p. 88)

We are each raised in some culture, and part of the socialization process we all experience is the acquisition of language. Much of language is a symbolic labeling system which provides us with ways of mentally "slicing up the world." Groups of events, objects, and ideas become lumped together in certain categories and thus distinguishable from one another and yet relatable. The more one knows about a certain category - that is, what is contained within that category, what similarities exist between members of the category, and how these differ from nonmembers, etc. - the better the concept is differentiated in cognitive structure. Words signifying categories provide economical and parsimonious ways of labeling. Thus when we speak of semantics, we are referring to the cognitive-conceptual content elicited by a given word-label or a combination of word-labels. The way in which words are combined, utilizing the rules or the grammar of the language, falls into the domain of syntactics. Certainly there is no hard line between the syntax and the semantics of a language; and indeed the actual usage of language falls into the more practical domain of pragmatics.

Thus a child who has acquired a language may communicate and, with the internal cognitive manipulation of concepts, she or he may think. Although thought and language can be considered as springing from separate sources (Vygotsky 1962), they become so elaborately intertwined that later in life, the two cannot be separated in the fabric of human cognition. Thus when we acquire a language, we possess more than a simple communication system; we have a system that, on the one hand, provides ways to view the world (i.e.

a pair of "conceptual goggles"), and, on the other hand, restricts our vision (see Whorf 1956). Just as a lens brings certain things into focus by blurring others, so language enables us to bring certain events into consciousness/clarity while other events are not recognized or are trivialized. Nevertheless, it is the conceptual content which underlies language that is of major importance.

I must emphasize that word and concept should not become confused. A word is, in essence, an arbitrary label which can be changed by cultural consensus. One can acquire certain concepts without ever learning the appropriate label. And, conversely, one can memorize or rote learn a word without acquiring the conceptual content which that word signifies. Furthermore, concept acquisition is an idiosyncratic process highly dependent on prior knowledge and experience. Thus two individuals can have radically different cognitive representations of the same concept designated by some word. When such a representation deviates from the accepted cultural norm, then we speak of misconceptions. But when the levels of sophistication differ, we speak of differences in the degree of conceptual differentiation in cognitive structures.

Throughout our education, we are acquiring new conceptual structures and languages. When we learn scientific (e.g. biological, physical, social, behavioral) languages, we acquire the corresponding conceptual frameworks which gradually replace portions of our intuitive knowledge, resulting in more precise and powerful tools of thought. The process is a slow one; new concepts become integrated into existing cognitive structure, inefficient concepts are rendered obsolete and are replaced, and all existing concepts are at various times undergoing further differentiation.

The process of acquiring a new language which entails no new concept acquisition is a different matter. For example, in acquiring a basic French or German vocabulary, we need only to replace certain words to signify already

differentiated cognitive content. Thus, "chien" or "hund" are recognized as equivalents of the English "dog." But, the rules for word combinations must also be learned in acquiring a new language; and thus one must learn the grammar so as to be able to transform the semantic structures into syntactically correct and thus comprehensible utterances.

Notice that this is a very different process than the acquisition of concepts. The latter always entails a substantive change in cognitive structure. Thus when one first learns the concept of "energy", it represents new cognitive content; and when food and batteries are recognized as alternative forms of potential energy and potential energy is distinguished from kinetic energy, then the concept of "energy" has become differentiated and more elaborate.

It is this process of concept acquisition that we deal with in this paper. This process is a process of meaningful learning; to be distinguished from rote learning. And I would contend that meaningful learning is one of the important functions of our schools.

## Concepts and the Process of Meaningful Learning

Before discussing the theoretical approaches to concept learning, and the empirical evidence to support or refute these theories, we should first be clear concerning our concept of "concept."

The concept of "concept" utilized in this paper is highly formalistic. Thus I should explain the limitations of such a model.

Concepts can be considered as categories, on the one hand, and as regularities, on the other. We refer to the extension of a concept as all of the members in the concept-category. We consider the intension of a concept as the regularities or critical attributes or rules which enable one to decide whether X is a member or nonmember of that category. This simple, formal re-

presentation of concepts can be depicted as a cone, seen in Figure 1.

Place Figure 1 about here.

Notice that one can acquire a concept by learning the members of a category and then extracting from their similarities/differences, the rule or criterial attributes used in making the categorization. On the other hand, one can learn the regularity and then generate the extension of the category. The first method is an inductivistic approach whereby the essence of the concept is gradually recognized by experiencing numerous members of that concept. We shall call this process "bottom up."

The second method is a more parsimonious approach whereby the "essence" or "criterial attributes" are pointed out and thus the cateogry elements can be immediately generated and recognized. We shall call this approach "top down."

Both of these processes can be forms of meaningful learning. That is, if the new information is incorporated into cognitive structure in a substantive and non-arbitrary way, it is related to previous knowledge and is thus meaningful.

In the past, there has been confusion about what is to be considered meaningful learning. It was believed that reception learning (i.e. information not discovered but received in some fashion through, for example, books, teacher talk, media presentations, etc.) must necessarily be rote, and that only independent discovery learning is truly meaningful. This confusion results from unclear thinking about two completely <u>independent</u> dimensions or continuums: the rote - meaningful continuum and the reception - discovery continuum. As the realities of school learning have, for many reasons, usually involved the efficient mode of meaningful reception learning, we have witnessed greater demands on this specific teaching-learning process. How this process occurs is indeed the subject of this investigation.

Before describing the methods of investigation, a number of disclaimers about the concept of "concept" developed thus far in this section, are in order. Concepts are not rigid categories! It makes little sense to speak of conceptual extensions as if concepts had clear-cut borders. It makes little sense to speak of criterial attributes as if they really existed. Rather, conceptual boundaries are fuzzy and the regularities are a crossroads of numerous criterial attributes. Thus they are often indeterminate. Concepts are flexible enough to enable short-term changes in individual cognitive structures and long-term changes in disciplined knowledge; while maintaining enough stability to make them meaningful and to overlap in different cognitive structures enabling communication.

We must remember that concepts are a cultural phenomena and exist as a consequence of those concept-users who invent them, learn them, and use them. Concepts and conceptual frameworks are evolving structures that parsimoniously summarize human experience and are thus the basis of school learning.

## Methods of Investigation

This investigation was carried out within the framework of the Audio-Tutorial Elementary Science Project (A-TESP) at Cornell University (Novak 1977, Pines 1978 ). Children were provided with 24 audio-tutorial lessons which deal with the concepts of "energy", "life", and "molecule" (Pines 1977).

Prior to the lessons, children were interviewed to ascertain existing relevant cognitive structure. Then subsequent to each block of 8 lessons (3 blocks were operating during the school year), the children were again interviewed so as to evaluate resultant changes.

Two methods were developed and refined for this study:

1) The Modified Piagetian Clinical Interview (MPCI) and

2) The Conceptual Propositional Analysis (CPA).

Only a brief outline of these methods can be reported here; their elaboration is beyond the scope of this paper. Information concerning these methods can be found in Pines et al. (1978) and Posner et al. (1977).

The MPCI format is depicted in Figure 2. The child is presented with a phenomenon and is asked for a prediction, description or explanation. Through a skillful process of following up on responses, some portions of the child's relevant existing cognitive structure are "probed" and thus "exposed." Relevant exemplars are presented in Figures 3 and 4.

All interviews were taped and then transcribed. The interview data were transformed into propositional format. A conceptual propositional analysis (CPA) was carried out so as to compare the Pre-Instructional responses with Post-Instructional responses.

Although 126 children were originally interviewed, only portions of two comparative case studies will be reported here. The CPA data are bulky and thus only two segments are presented. However, these summarize the alternate modes of concept internalization. Both segments deal with the acquisition of the concept of "energy."

Data and Analysis

Tables 1 and 2 are examples of Pre - Post Instructional Interview comparisons. Each clearly exemplifies concept learning.

In the first case, a shift in criterial attributes or regularities is observed; whereas in the second case, we evidence a change in the extension of the concept.

The two modes of learning are further summarized in Figures 5 and 6. Notice that in the first example, the intension of the concept is directly challenged. Subsequent to change, the concept is rendered more applicable to exemplars not previously related, i.e., the concept now entails a wider

and more precise extension. We can label this type of learning "top down."

In the second example, we do not distinguish an explicit change in regularities or conceptual attributes. Rather, we recognize the conceptual change in terms of the expansion of the extension of the concept. Phenomena previously not recognized as belonging to the extension of the concept are later incorporated. Because the concept is changed with the incorporation of additional exemplars into the extension, we call this mode of learning "bottom up."

Both modes of learning, "top down" and "bottom up", involve conceptual change. They are important routes to the acquisition of concepts. It should be emphasized that these modes of concept learning are different only at a theoretical level; because, inevitably, when the extension of a concept changes, so does its intension and vice versa. However, this theoretical distinction does have important implications for teaching.

## Conclusions, Ramifications, and Implications for Teaching

The major conclusion resulting from this study is that we can distinguish different modes of concept acquisition. Two prototypes, one designated as "top down" and the other as "bottom up", were identified subsequent to an empirical investigation and the analysis of data.

Due to the fact that the teaching and learning of concepts constitutes a major function of schooling, the results of this study may prove useful. In both cases, "top down" and "bottom up" learning, we evidence conceptual change. And, indeed, the teacher may capitalize on both modes of concept acquisition in teaching large bodies of conceptual content.

In many cases, a student will exhibit a misconception by overemphasizing an accidental attribute as if it were a criterial attribute:

e.g. "Alive means that things are squeezeable".

We may choose to deliberately alter this criterion by directly supplying

alternative criteria:

e.g. "Things that are alive grow."

"Things that are alive reproduce."

"Many things that are alive move voluntarily."

This you will recognize as an attempt towards "top down" learning. Also, whenever we supply a definition in an attempt to introduce new concepts or to relate existing concepts, we are engaging in "top down" learning. Ausubel's (1968) ideas of "organizers" - both expository and comparative - are classical examples of attempts to bring about concept learning utilizing a "top down" approach.

The alternative would be to supply prototype exemplars to illustrate the concept application and then further differentiate the concept by comparing the prototype exemplars to borderline exemplars, and to non-exemplars. And we can create cogntive dissonance by providing counter examples which contradict and therefore empirically render the child's definitions faulty. For example, if the child's definition of "life" entails "squeezeability", we can provide examples of living things that are non-squeezeable and of squeezeable things that are not alive. In light of such recalcitrant information, the child (if rational) will be forced to reformulate definitions and meanings.

In effect, both of these modes of instruction can and should be employed simultaneously. Exemplars should be provied while emphasis is placed on the criteria which qualify the exemplar as a member of the extension of the concept. What should be avoided is the fact-feeding in the form of numerous statements which serve no further purpose in bringing about conceptual change.

The teacher should always be engaged in an attempt to bring about substantive changes via concept learning and differentiation. And the examples illustrated in this paper provide insights into two alternative ways which can and should be used at the same time.

Finally, this paper would not be complete without a brief mention of at least two prerequisites necessary for a teacher to facilitate concept learning:

1) The teacher needs a profound understanding of the subject matter domain which s/he purports to teach (i.e. teachers need to be experts!). Without such a fundamental grasp the teacher cannot decide which concepts are central and of importance (i.e. develop a curriculum) nor decide how to go about teaching those concepts (i.e. develop instructional techniques). The teacher, in short, needs what Gowin (1977) calls a "knowledge of knowledge." Thus the syntax (i.e. methods) as well as the substance (i.e. concepts) of disciplined knowledge can be taught and learned within the confines of their validity (Schwab 1960, 1962, 1964). Such teaching will necessarily be both enquiry and conceptually oriented providing the students with the necessary tools of thought.

2) The teacher needs to have some information concerning what the student knows: a) Only if the teacher knows what misconceptions exist, can s/he rectify these misconceptions. And b) by knowing more about the students' existing cognitive structure, the teacher can choose pertinent exemplars for teaching (i.e., instrumental content, see Johnson 1967, 1977). Both of these issues are clearly illustrated in the empirical portion of this paper. Ways in which teachers can get a better grasp on the student's prior knowledge have been discussed by this author elsewhere (see Pines 1978a).

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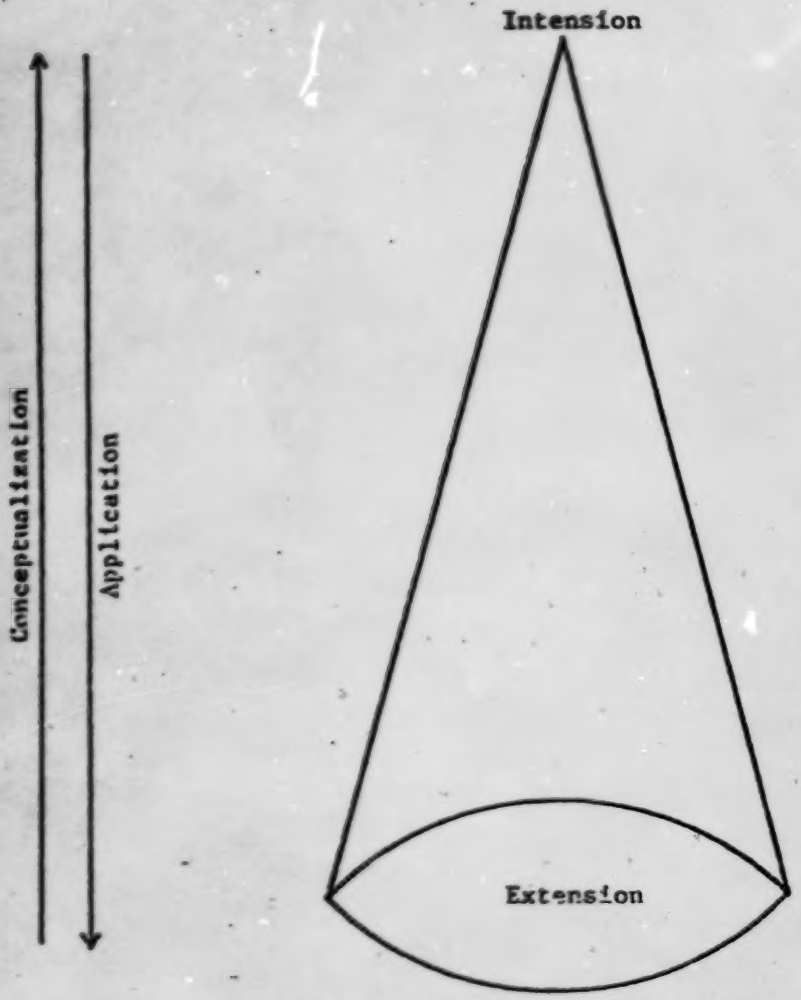
The qualities, properties, or attributes, viz. the commonalities, which a term signifies, i.e. connotation.



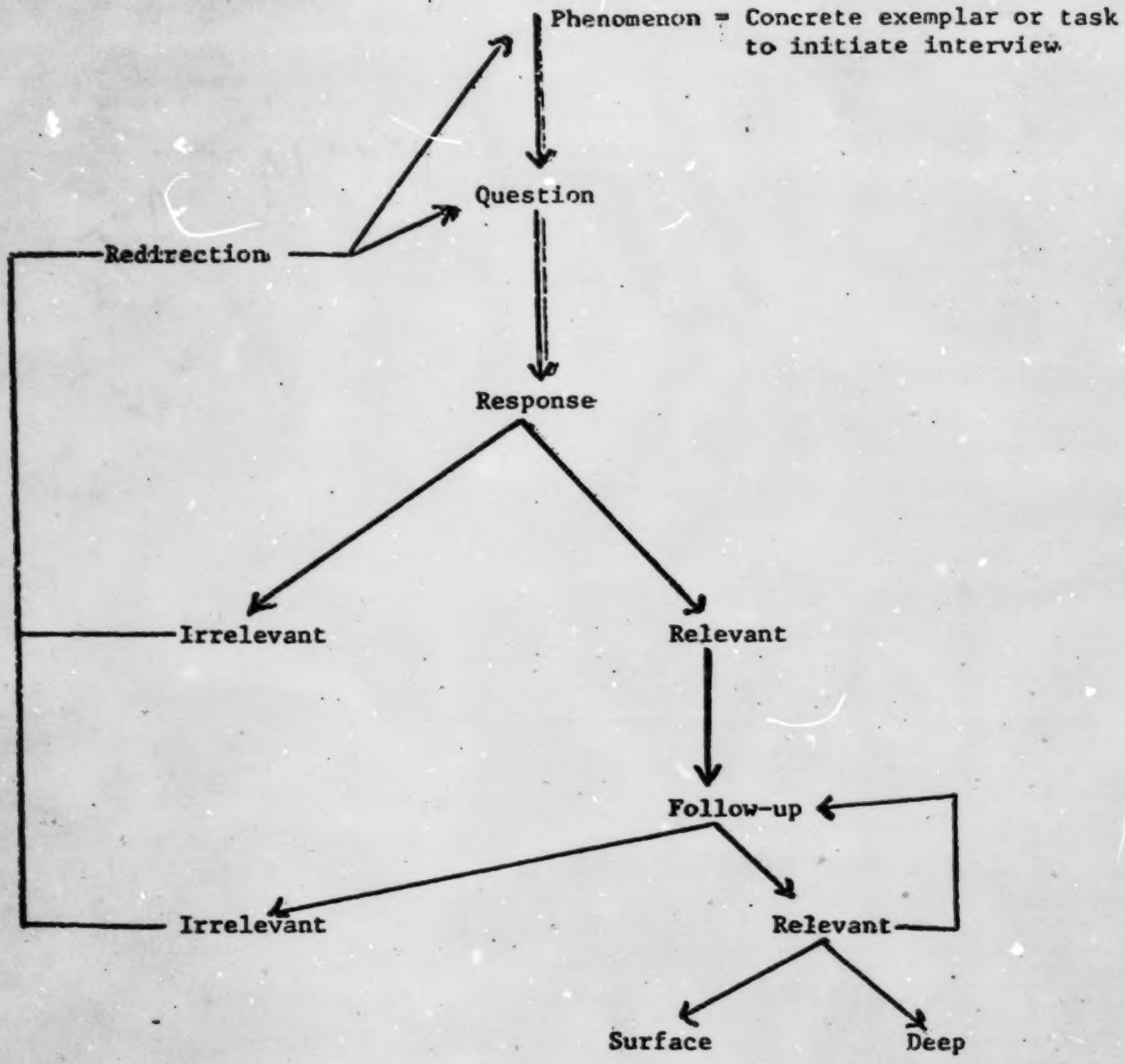

Regularities, criterial attributes, rules, etc. which distinguish between members and non-members.

The class of entities, viz. members of the category, to which the term applies, i.e. denotation.

Figure 1.

The "Conic Schema" of a Concept.

A crude representation of the concept of "concept".




**The Modified Piagetian Clinical Interview (MPCI) Format.**

Figure 2. The MPCI Format

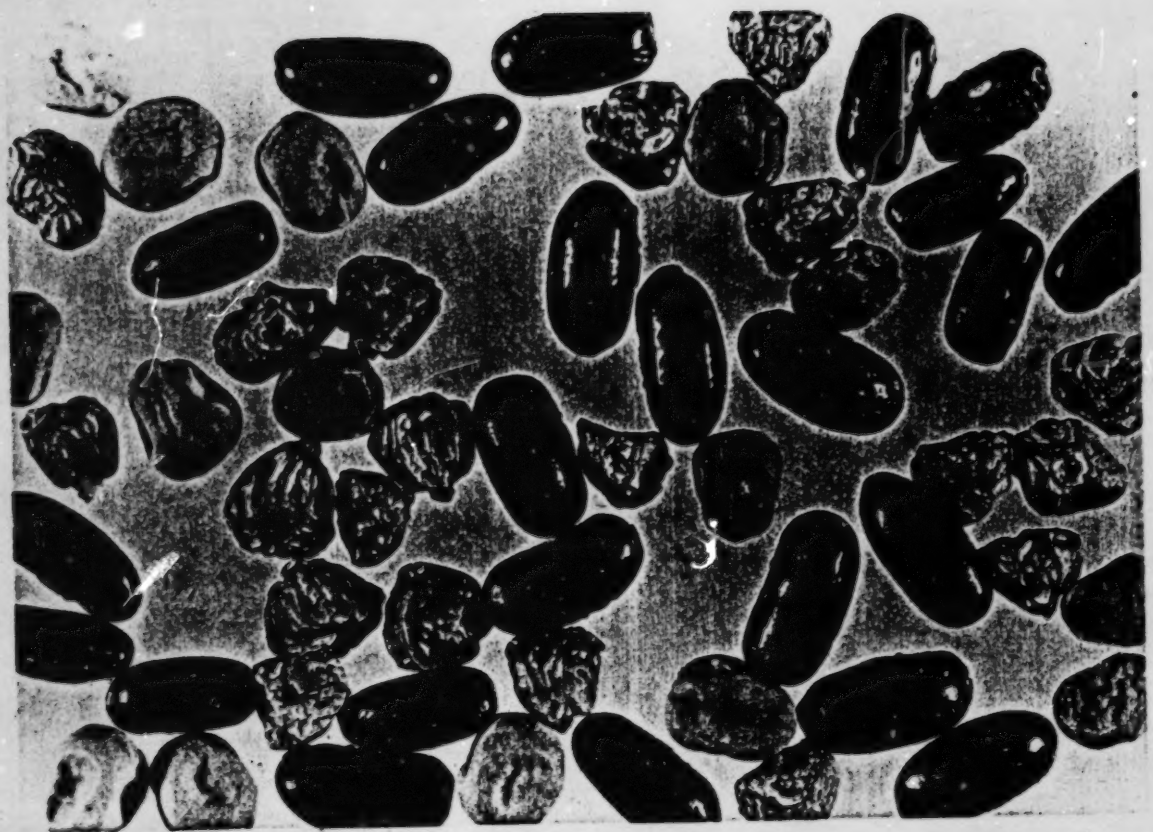


Figure 3. Exemplar Used to Initiate Interviews.

Figure 4. Exemplar Used to Initiate Interviews.

## Case Study 1 - Concept Learning Observed as a Shift in Emphasis of Criterial Attributes.

Table 1.

| Pre II | Post II |
|---|---|
| 3. Real seeds are alive because you can squeeze real seeds but you can't squeeze phoney ones. | 8. There is nothing you can do to make them (seeds) grow because they might be dead and if they're dead they won't grow |
| 17. I am alive. | 9. To check if they're (seeds are) alive, you have to wait for a few days and if there's water, light and air they might grow into big plants |
| 18. Plants are alive. | 10. If they (seeds) do grow, they're alive. |
| 19. Alive means that you grow | 11. Alive means that it grows big and tough |
| 20. Grow means you can move like the wind blows and helps the corn to move | 19. I am alive |
| 21. Wind moves and people move all the time | 20. Plants are growing that means they're alive |
| 32. Wind is alive | 21. If you're alive you grow too |
| 84. You know ants are alive because they're animals and they walk around | 23. that means she (grandma) can't move anymore |
| | 26. When they go to sleep they're still breathing |
| | 27. The sun isn't breathing; the sun isn't alive |
| | 28. The corn plant is alive; the corn plant gets taller and taller, gets real big |
| | 29. The bears get lots of corn and they grow big and fat |
| | 30. When the kid gets lots of food, she gets bigger and tougher; she may still get skinnier |
| | 32. These are seeds, they're alive |
| | 33. These are pieces of wood; they were alive; they are dead now, but they were alive because they could be alive and grow up, could be part of the trunk and could grow branches... |

## Case Study 2 - Food and Food Chains
## (the picture series task)

Table 2.

| Pre II | Post II |
|---|---|
| 6. Some kinds of seeds you can eat | 19. Food makes people alive |
| 21. There is no connection between the sun and the corn | 29. You eat cereal so you can get energy so you can move and talk |
| 22. The chickens eat corn | 34. The sun makes the corn seeds grow then they pick it and drop it and the chickens eat it |
| 23. I don't know why chickens eat corn | 36. There is a connection between these pictures - these two (sun and corn plant) because the sun makes the corn grow |
| | 37. The sun helps the corn grow |
| | 39. The corn plant came from the sun and the corn (chickens are eating) came from the corn plant |
| | 40. It would make sense to call this a food chain because this is food and this is food and this (chickens) could be food if you killed it |
| | 62. The sun is shining down on the corn so the corn will grow |
| | 63. The sun is shining down on the corn stalk so the corn stalk will grow |
| | 64. Energy does it (causes growth) |
| | 65. When the corn grows the corn has energy inside it |
| | 66. Corn needs hot air sometimes; hot air helps the corn grow |
| | 67. The chickens are eating corn because they need corn for their energy |
| | 68. The corn gets energy from the sun |
| | 69. These pictures are like a food chain because the sun helps the corn grow and the corn helps the chickens and girls grow and chickens make kids grow and parents grow |

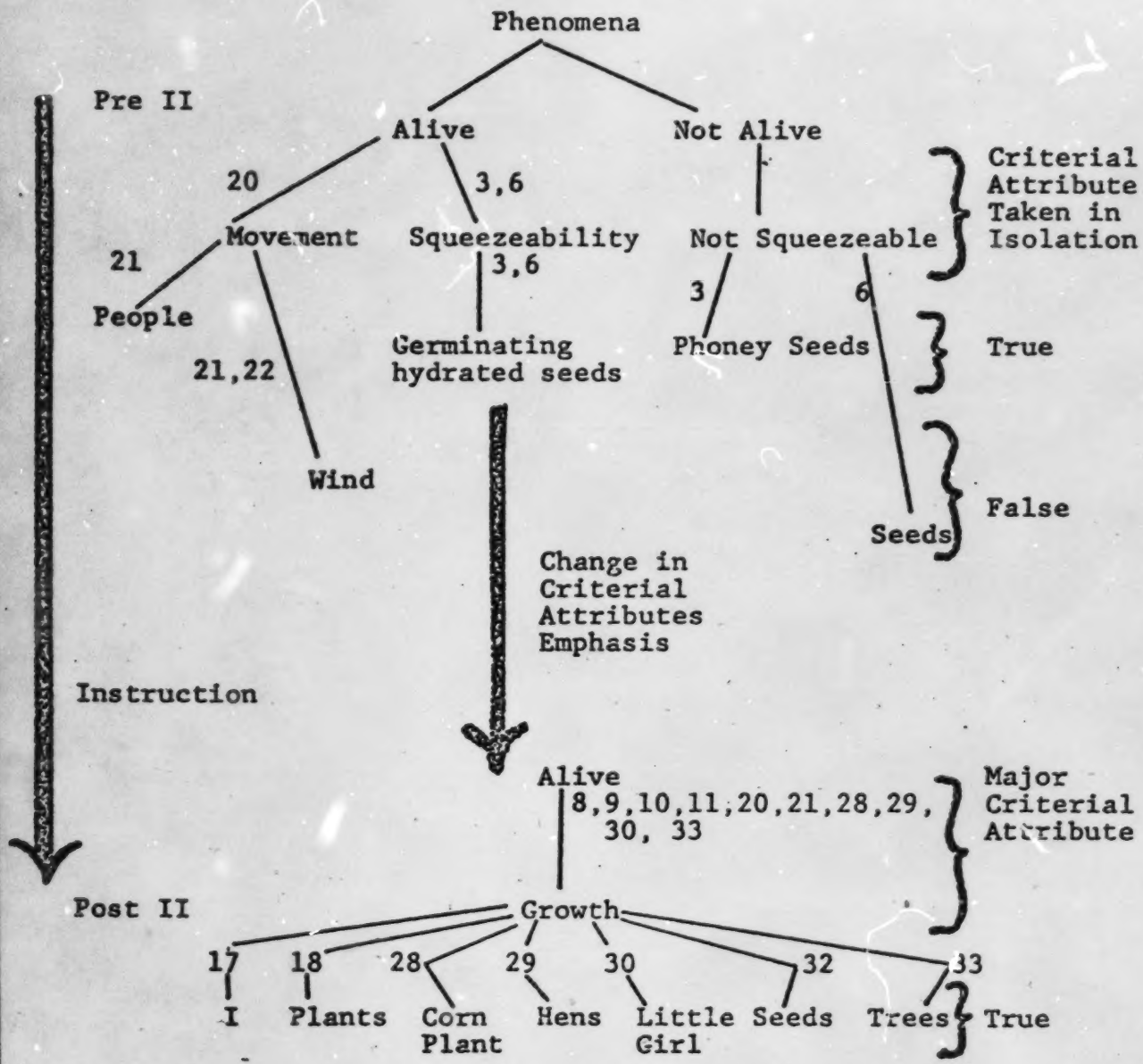



Figure 5.

Learning Observed as a Shift in Emphasis of Criterial Attributes.

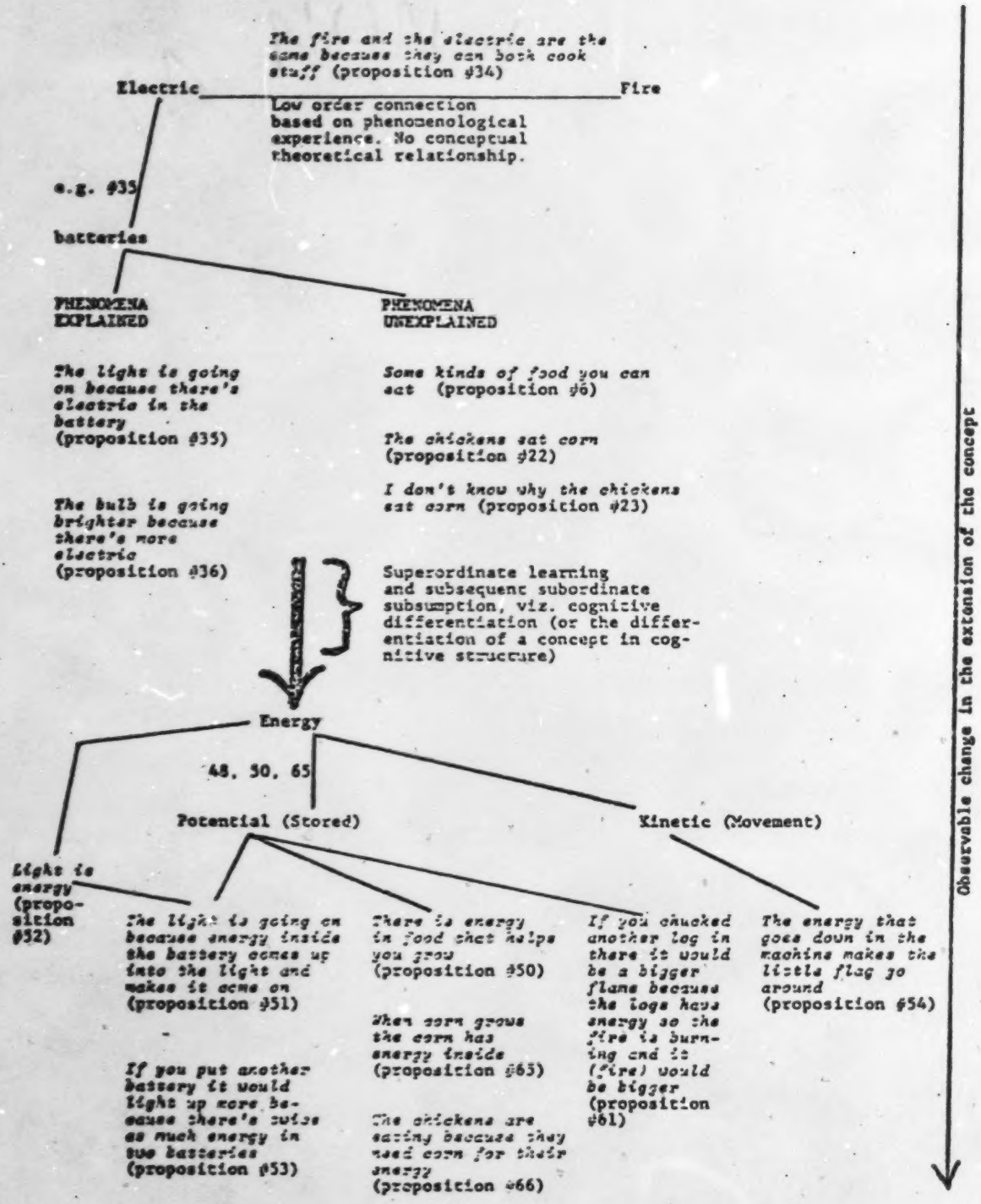

The fire and the electric are the same because they can both cook stuff (proposition #34)
Electric
Fire
Low order connection based on phenomenological experience. No conceptual theoretical relationship.
e.g. #35
batteries
PHENOMENA EXPLAINED
PHENOMENA UNEXPLAINED
The light is going on because there's electric in the battery (proposition #35)
Some kinds of food you can eat (proposition #6)
The chickens eat corn (proposition #22)
I don't know why the chickens eat corn (proposition #23)
The bulb is going brighter because there's more electric (proposition #36)
Superordinate learning and subsequent subordinate subsumption, viz. cognitive differentiation (or the differentiation of a concept in cognitive structure)
Energy
48, 50, 65
Potential (Stored)
Kinetic (Movement)
Light is energy (proposition #32)
The light is going on because energy inside the battery comes up into the light and makes it come on (proposition #51)
If you put another battery it would light up more because there's twice as much energy in two batteries (proposition #53)
There is energy in food that helps you grow (proposition #50)
When corn grows the corn has energy inside (proposition #63)
The chickens are eating because they need corn for their energy (proposition #66)
If you chucked another log in there it would be a bigger flame because the logs have energy so the fire is burning and it (fire) would be bigger (proposition #61)
The energy that goes down in the machine makes the little flag go around (proposition #54)
Observable change in the extension of the concept

Figure 6.

Learning Observed as a Change in the Extension of a Concept